UNIT –II

Data Input and Geometric transformation: Existing GIS data, Metadata, Conversion of existing data, Creating new data, Geometric transformation, RMS error and its interpretation, Resampling of pixel values.

Existing GIS Data

Clearinghouses and webportals:-

- A repository structure, physical or virtual, that collects, stores, and disseminates information, metadata, and data.
- A clearinghouse provides widespread access to information and is generally thought of as reaching or existing outside organizational boundaries.
- Clearinghouse refers to a website from which we can download GIS data.
- A clearinghouse is sometimes called a warehouse.
- A clearinghouse is mainly concerned with data collection not with services for data query.
- A portal provides multiple services, which include a directory of websites, links to other sites, news, references, a community forum etc.
- A portal is called "Gateway".
- A web portal is most often one specially designed web page at a website which brings information together from diverse sources in a uniform way.

Federal Geographic data committee:-

- The federal Geographic Data Committee (FGDC) is a 19 member interagency committee.
- FGDC leads the development of policies, metadata standards, and training to support National Spatial Data Infrastructure.

Geospatial One-Stop:-

- The Geospatial One-Stop is a geospatial data portal established by federal office of management and budget in 2003.
- The main objective of GOS is to expand collaborative partnerships at all levels of government to help leverage investment in geospatial data.

Statewide Public data:-

- The Geospatial One-Stop website provides a link to every state in United States for statewide GIS data.

Regional public Data

Metropolitan Public Data

County-level public data

Regional public data

GIS data from private companies

Metadata

- Information that describes the content, quality, condition, origin, and other characteristics of data or other pieces of information.
- Metadata for spatial data may describe and document its subject matter; how, when, where, and by whom the data was collected; availability and distribution information; its projection, scale, resolution, and accuracy; and its reliability with regard to some standard.
- Metadata consists of properties and documentation.
- Properties are derived from the data source (for example, the coordinate system and projection of the data), while documentation is entered by a person (for example, keywords used to describe the data).
- FGDC metadata standards describe a data set based on following categories

  o **Identification Information: -** Basic information about the data set, including data, geographic data covered, and accuracy.

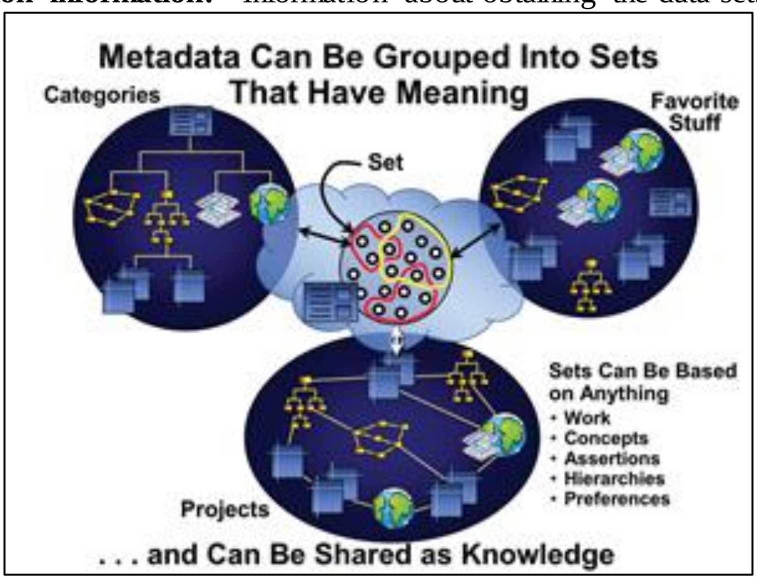
  o **Data Quality Information: -** Information about the quality of the data set, including positional and attribute accuracy, completeness, consistency, sources of information etc.

  o **Spatial data organization information: -** Information about the data representation in data set, such a method for data representation (eg. Raster or vector) and number of spatial objects.

  o **Spatial Reference Information: -** Description for the reference frame for, and means of encoding coordinates in the data set, such as the parameters for map projections or coordinate system.

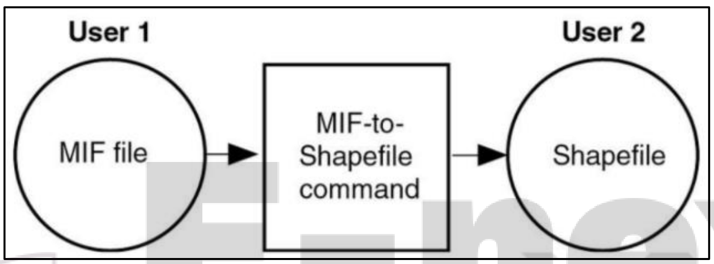
  o **Entity and attribute information: -** Information about the content of data set such as entity types and their attributes and the domains from which attribute values may be assigned.

  o **Distribution information:-** Information about obtaining the data set.



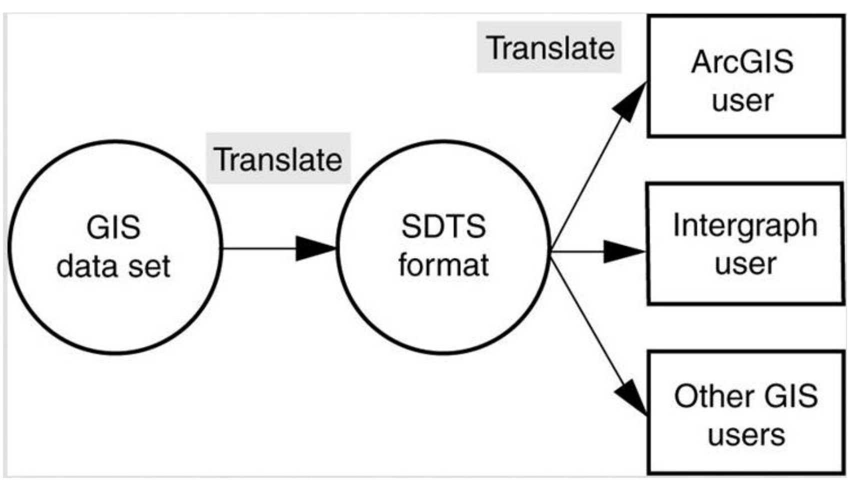
Conversion of Existing Data:-

- Public data are delivered in variety of formats.
- Unless the data format is compatible with the GIS package in use, we must first convert the data.
- Data conversion is defined as the mechanism for converting GIS data from one format to other.
- Data conversion complexity depends on the specificity of the data format.
- Proprietary data formats require special translator for data conversion whereas neutral or public format requires a GIS package that has translators to work with format.
- **Direct Translation:-**
  o Direct Translation uses a translator in a GIS package to directly convert Geospatial data from one format to another.
  o Direct translations used to be the only method for data conversion before the development of data standards and open GIS.
  o Figure 1



  o MapInfo files (MIF) can be converted to a shape file or geodatabase using "MIF to Shape file tool in ArcGIS".

- **Neutral Format**:-
  o A neutral format is public or de facto format for data exchange.
  o In Direct Translation we need to have translators for every inter format conversion. So the need arises to reduce the need of separate translator for every format change.
  o The Spatial Data Transfer Standard (SDTS) is a neutral format .Several Federal agencies have converted their data to SDTS format.
  o So in neutral format GIS packages have translators to work with the formats.
  o Fig 2



Creating New Data

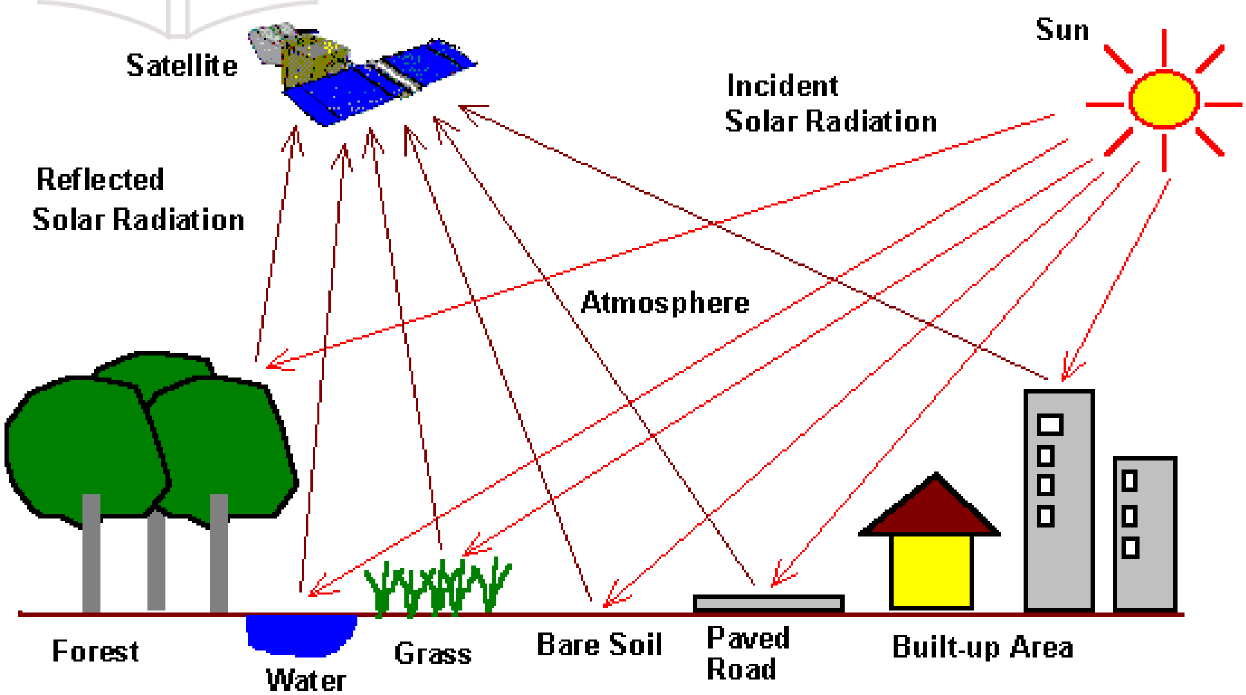
- Spatial data can be obtained from various sources.
- It can be collected from scratch using Direct Spatial Data Acquisition technique or by making use of existing spatial data collected by others.
- Data Acquisition can be grouped in two as Direct or Indirect.
- Direct Data Acquisition techniques include field survey data or remotely sensed data.
- Indirect Data Acquisition technique include digitizing, scanning etc.

Direct Spatial Data Capture:-

- It involves direct measurement of objects and phenomena. Given below is the partial list of primary data:

Remote sensing data capture:

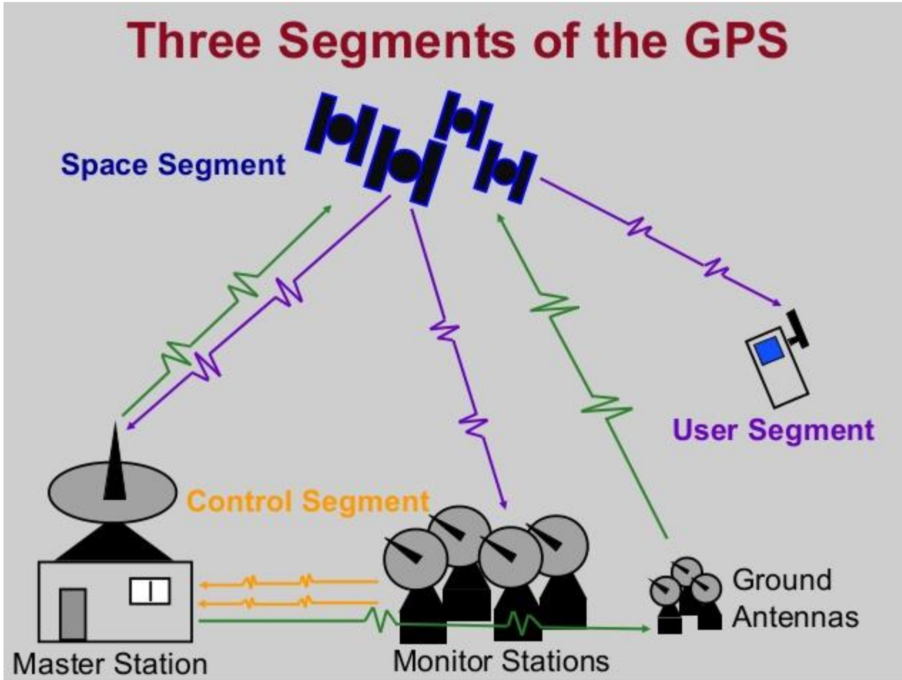
- Remote sensing refers to the technique of deriving the information about the objects without getting in physical contact with them.
- The information is derived from the measurements of the amount of electromagnetic (EM) radiations reflected, emitted or scattered from the objects under observation.
- The response is measured /captured by the sensors deployed in air or in space.
- The remote sensing data is often talked in terms of spatial, spectral and temporal resolutions.
- Spatial resolution: It refers to the size of the object that can be resolved and is the measure of the pixel size.
- Spectral resolution: It refers to the wavelengths of the EM spectrum in which response of the objects is captured.
- Temporal resolution: It refers to the frequency with which data is captured for the same area.



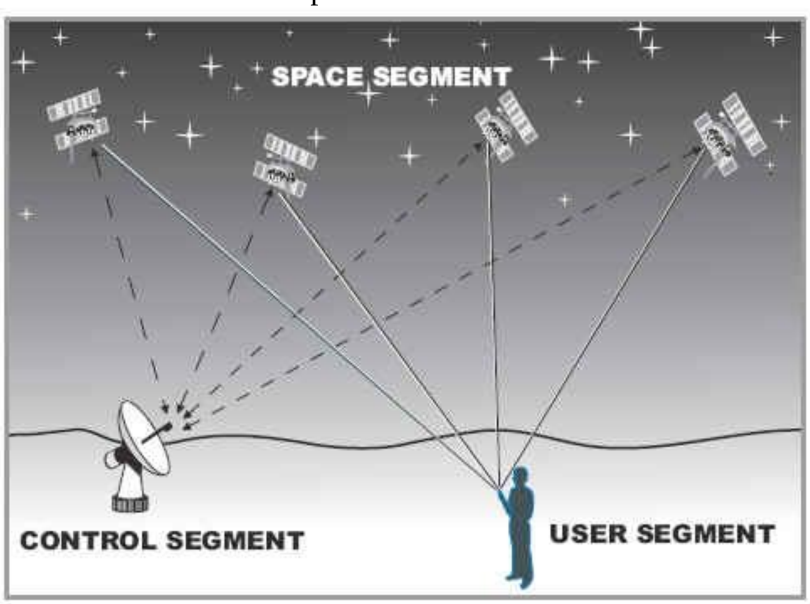
Aerial photographic data is as important as remote sensing data for a GIS project. Though both aerial photographs and remote sensing images are technically similar, they have few differences as well. The most notable difference is that aerial photographs are captured using analog optical cameras and are then rasterized by scanning a film negative.

Field Survey Data:

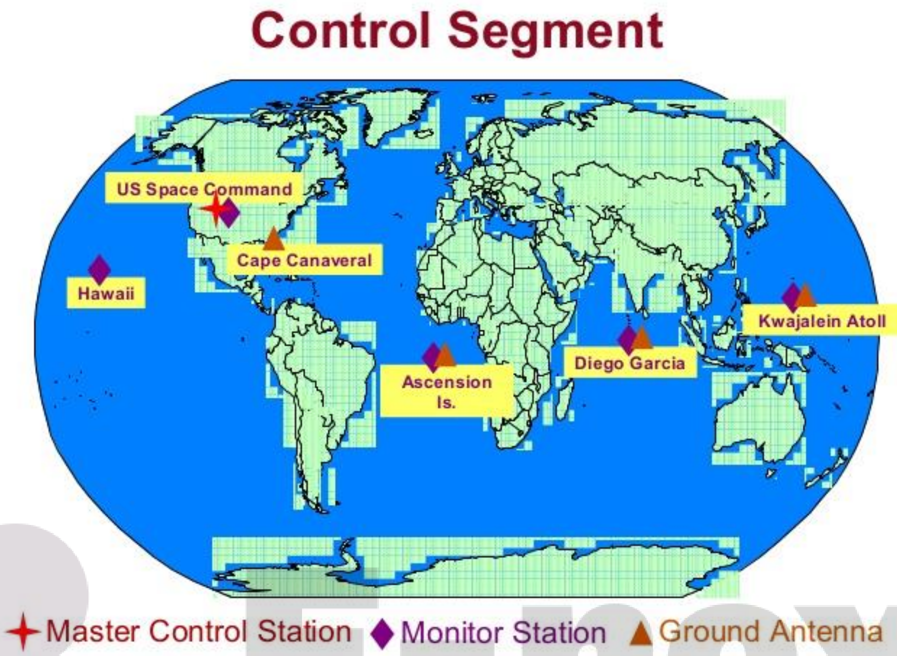
- **Two important types** of field data are survey data and global positioning system data.
  - **o Survey data**:-
    - Consists primarily of distances, directions and elevations.
    - Distances can be measured in feet or meters.
    - Direction of a line can be measured in azimuth or bearing angle.
    - Azimuth is an angle measured clockwise from the north end of the meridian to the line.
    - Azimuth ranges from 0 degree to 360 degree.
    - A bearing is an acute angle between a line and a meridian.
    - The bearing angle always has the accompanied letters that locate the quadrant (ie. NE, SE, SW, or NW) in which line falls.
    - An elevation difference between two points can be measured in feet or meters using levels and rods.
  - **o Global Positioning System Data:-**
    - A system of radio-emitting and -receiving satellites used for determining positions on the earth.
    - The orbiting satellites transmit signals that allow a GPS receiver anywhere on earth to calculate its own location through trilateration.
    - The system is used in navigation, mapping, surveying, and other applications in which precise positioning is necessary.
    - The GPS system consists of three major segments explained below:



- **Space Segment**
  - It consists of an all-weather global system of 24 satellites orbiting the earth every 12 hours in 6 orbital planes at an altitude of approximately 20,200 km.
  - The six equally-spaced orbital planes are inclined at 55° to the equator each having four "slots" for the satellites. The 24-slot arrangement ensures that from any point on the earth a GPS receiver can view at least four satellites.
  - The GPS satellites are powered primarily by solar panels, with Ni-Cd batteries providing secondary power. On board GPS satellites are the atomic clocks that provide accurate time.



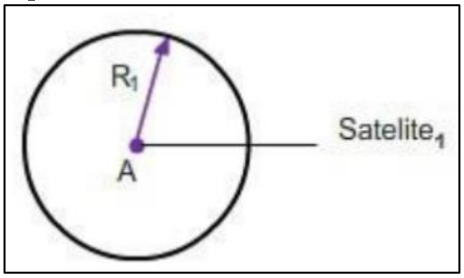
- **Control Segment:-**
  o GPS control segment is a network of ground facilities that track the GPS satellites, monitor their transmissions, and send commands and data to the constellation.



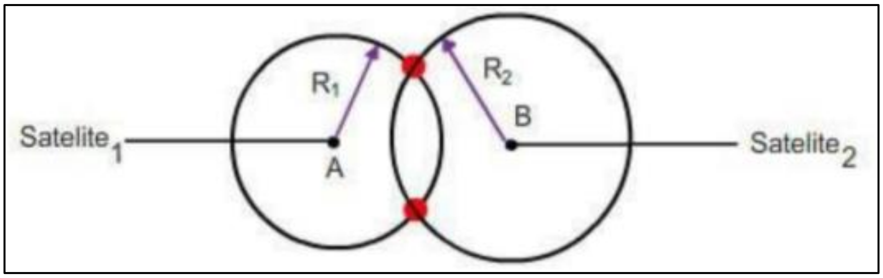
- **User Segment**
  o The user segment consists of GPS receivers and the users.
  o Principle: GPS works on the principle of trilateration i.e. determining absolute or relative locations of points based on the distances to at least three known positions.

Determining the location of a receiver

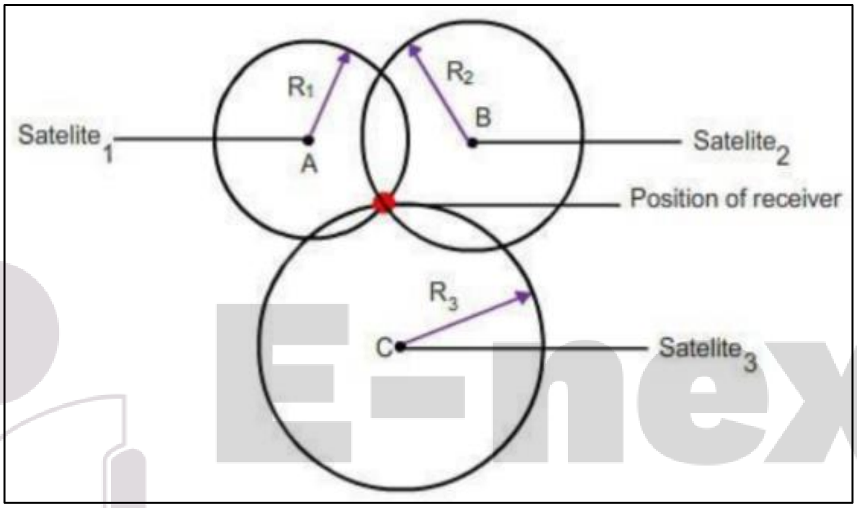
- GPS receiver calculates its distance from a satellite by measuring how long a signal from the satellite takes to reach it. It is implied that the receiver is located somewhere on the surface of an imaginary sphere centered at the satellite.



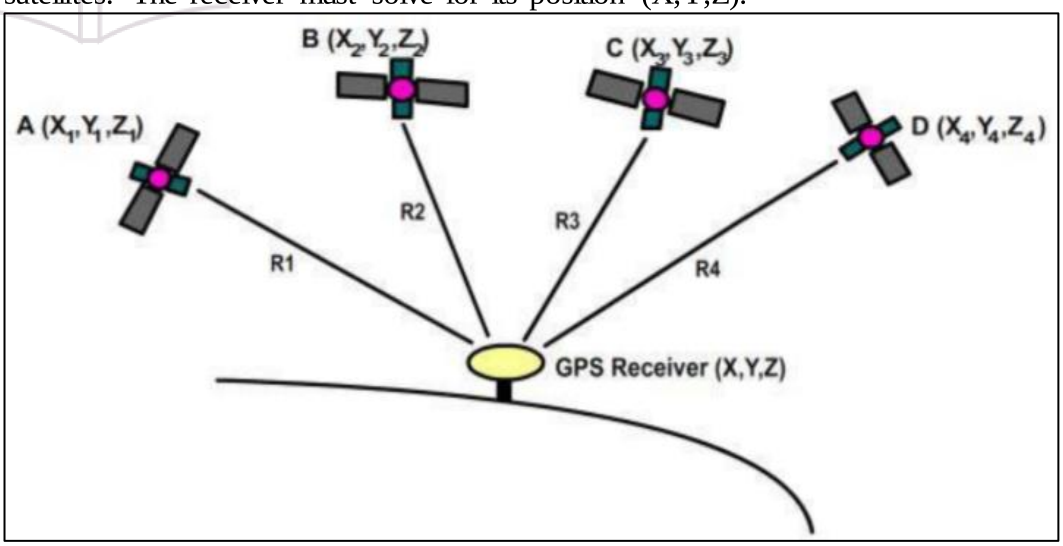
- The distance to the other satellite will also be calculated by the receiver. Similarly a sphere centered at B (satellite2) with a radius R2 can be imagined on whose surface lies the receiver.
- Since the receiver is R1 distance from A (satellite1) and R2 distance from B (satellite2), it is clear that the receiver will be on either of the points of intersection of the two spheres (shown by red dots).



- The distance calculated from the third satellite will add one more sphere to be imagined on whose surface lies the receiver. This gives rise to only one valid intersection i.e. the point where the three spheres intersect is the position of the receiver in a two dimensional space.



- A GPS receiver determines its position by using the signals that it receives from different satellites. The receiver must solve for its position (X,Y,Z).

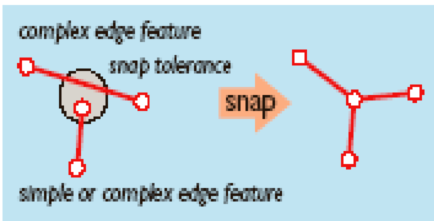


Indirect Spatial Data Capture:-

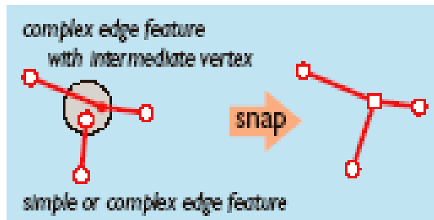
It refers to the data obtained from maps, hardcopy documents etc. Some of the methods to capture secondary data are as follows:

Digitization: Digitizing is the process of interpreting and converting paper map or image data to vector digital data.

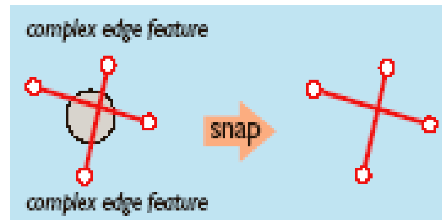
- Manual digitizing uses a digitizing table.
- A digitizing table has a built in electronic mesh, which can sense position of the cursor.
- To transmit the x-, y- coordinate of a point to the connected computer, the operator simply clicks on a button after lining up the cursor's cross hair with the point.
- **Snapping:-**
  o An automatic editing operation in which points or features within a specified distance (tolerance) of other points or features are moved to match or coincide exactly with each other's coordinates.



Connectivity is established. Intersection detection is performed along complex edges, and new vertices are inserted as required.



Connectivity is established. Mid-span connectivity on complex edge features is established in snapping.



No connectivity is established. Connectivity must be at an endpoint of one of the two edge features.

Digitizing Point:-

- Digitizing point is easy.
- Each point is clicked once to record its x and y coordinate.

Digitizing line:-

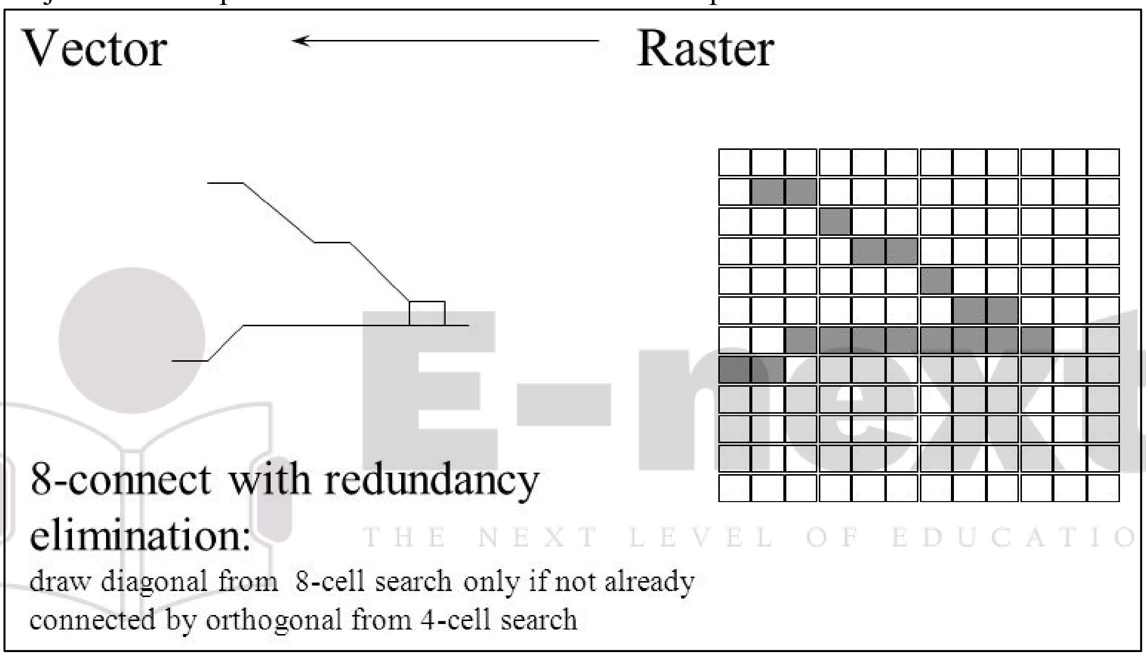
- Digitizing line feature can follow either point mode or stream mode.
- **Point mode:** In this mode, digitization is started by placing a point that marks the beginning of the feature to be digitized and after that more points are added to trace the particular feature (line or a polygon). The number of points to be added to trace the feature and the space interval between two consecutive points are decided by the operator.
- **Stream mode:** In stream digitizing, the cursor is placed at the beginning of the feature, a command is then sent to the computer to place the points at either equal or unequal intervals as per the position of the cursor moving over the image of the feature.

Scanning:-

- A scanner is used to convert analog source map or document into digital images by scanning successive lines across a map or document and recording the amount of light reflected from the data source.
- A scanner converts an analog map into a scanned image in raster format.
- Documents such as building plans, CAD drawings, images and maps are scanned prior to vectorization. Scanning helps in reducing wear and tear; improves access and provides integrated storage.

Vectorization:-

- Vectorization is the process of converting a raster image into a vector image.
- It is a faster way of creating the vector data from raster data.
- Automatic vectorization is performed in either batch or interactive mode.
- Batch vectorization takes one raster file and converts it into vector objects in a single operation. Post vectorization editing is required to remove the errors.
- In interactive vectorization software is used to automate digitizing. The operator snaps the cursor to a pixel and indicates the direction in which line is to be digitized. The software then automatically digitizes the line.
- The operator can decide various parameters such as density of points, whether to pause at junction for operator's intervention or to trace in a specific direction etc.



Geometric Transformation:-

- Geometric Transformation is the process of using set of control points and transformation equation to register a digitized map, a satellite image, or an aerial photograph onto a projected coordinate system.
- When you rectify a raster dataset, project it, convert the raster dataset from one projection to another, or change the cell size, you are performing a geometric transformation.
- Geometric transformation is the process of changing the geometry of a raster dataset from one coordinate space to another.
- The process of geometric transformation requires a set of control points and transformation equations to register a digitized map, a satellite image, or an aerial photograph onto a projected coordinate system.
- It is commonly used in GIS to transform maps between coordinate systems.

Map-To-Map Transformation

- Geometric transformation converts a newly digitized map into projected coordinates

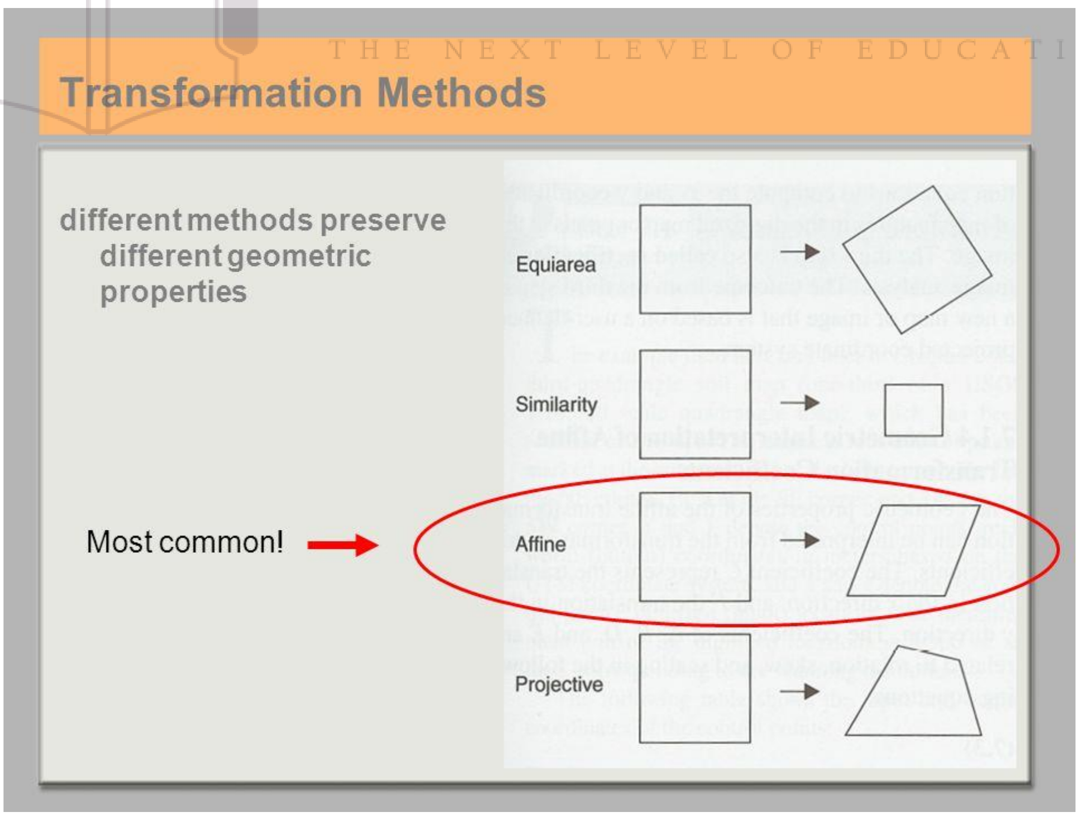
- A manually-digitized map has the same measurement as its source map: measured in inches
- A converted scanned image of the map is measured in dots per inch (dpi)
- To make the digitized map usable in GIS – it must be converted into a projected coordinate system to align with other layers.
- Geometric transformation also applies to satellite imagery.

Image-To-Map Transformation

- Remotely sensed data transformation involves changing row and columns
- Can spatially register a georeferenced image in a GIS database
- Must have same coordinate system.
- The rows and columns can be transformed into a projected coordinate system.
- Geometric errors can be corrected at that time as well

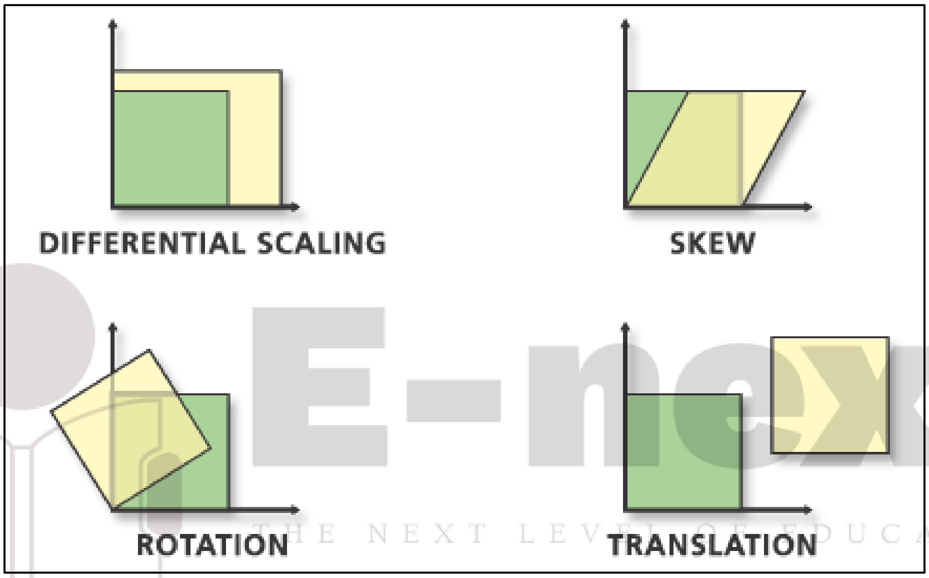
Transformation Methods

- Each transformation method can preserve certain geometric properties of the data.
- The effect of transformation varies from change of position and direction, to a uniform change of scale, and to changes in shape and size.
  o **Equi-area (Euclidean):** allows rotation of a rectangle and preserves shape and size
  o **Similarity:** allows rotation of rectangle and preserves shape, but not size
  o **Affine:** allows angular distortion of rectangle, but preserves parallelism of lines
  o **Projective:** allows both angular and length distortion, allowing rectangle to be transformed into an irregular quadrilateral.



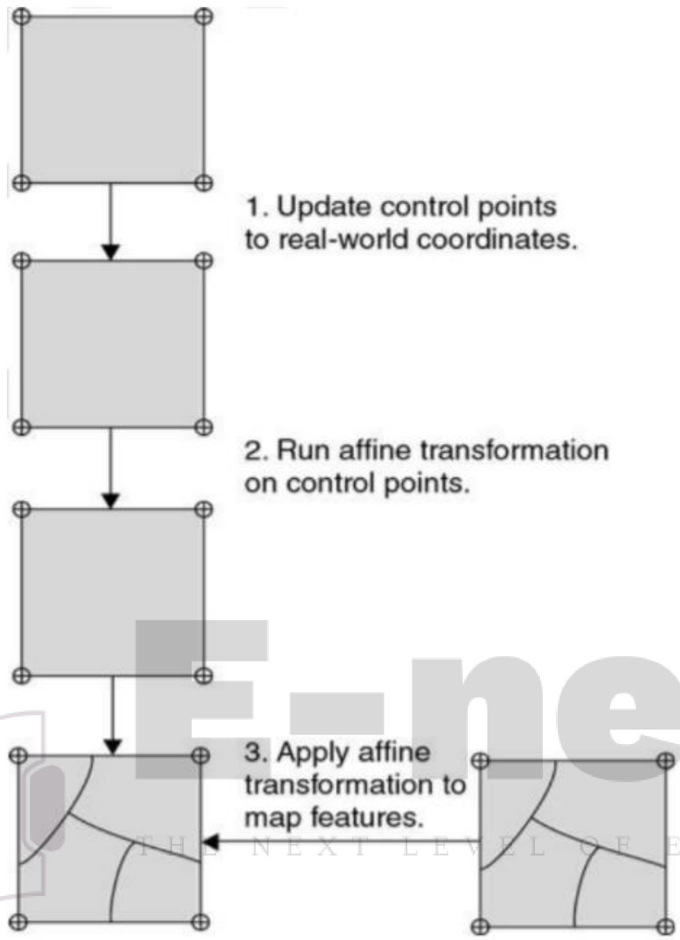
Affine Transformation

- The Affine Transformation allows rotation, translation, skew and differential scaling on a rectangular object.
- The Affine Transformation allows rotation, translation, skew and differential scaling on a rectangular object.
- Rotation: rotates objects x- and y-axes from the origin
- Translation: shifts the origin to a new location
- Skew: allows for non-perpendicularity (or affinity) between the axes, changing the shape to a parallelogram with a slanted direction
- Differential scaling: changes the scale by expanding or reducing in the x and/or y direction.



- Mathematically, the affine transformation can be expressed as a pair of first-order polynomial equations:
  - o $X = Ax + By + C$ -> (1)
  - o $Y = Dx + Ey + F$ -> (2)
- Where x and y are the input coordinates, X and Y are the output coordinates to be determined and A, B, C, D, E, and F are the transformation coefficients
- The two equations apply to both digitized maps and satellite images with two differences:
  o x and y represent point coordinates in digitized maps, but they represent columns and rows in a satellite image.
  o The coefficient E is negative in satellite images
- the origin for satellite images is in the upper-left corner
- the origin for projected coordinate systems is in the lower-left corner
- Three steps:
  o Update the x and y coordinates of selected control points to real-world coordinates
  o Derive by projecting longitude and latitude values of points
  o Run an affine transformation on the control points and examine the RMS (Root Mean Square) error
  o If the RMS error is higher than expected, use different set of control points

o Use the estimated coefficients and the transformation equations to compute the new x- and y-coordinates of digitized map or pixels in the image



Outcome: A new map or image that is based on user-defined projected coordinate system

Control Points

- Control points are selected from real-world coordinates
- A USGS 1:24,000 scale quadrangle map has 16 control points with known latitude/longitude
- Each control point is called a 'tic'
- An affine transformation requires a minimum of three control points to estimate the 6 (A-F) coefficients
- Four or more needed for better accuracy
- After the control points are selected, they are digitized along with the map features onto the digitized map
- The coordinates of these control points are the x, y values and the real-world coordinates of these control points are the X, Y values
- Estimate of Transformation Coefficients
- Using a quadrangle map, four control points can be used:
- X and Y represent control points real-world (output) coordinates in meters

- x and y represent control points digitized (input) locations

Image Transformation

Ground Control Points

- Ground Control Points (GCPs) are points both image coordinates (in rows and columns and real-world coordinates can be identified.
- Using the previous equations:
- x, y values represent the image coordinates
- X, Y values represent the real-world coordinates

ROOT MEAN SQUARE (RMS) ERROR

- Root Mean Square (RMS) Error measures the deviation between the actual (true) and estimated (digitized) locations of the control points.
- Deriving the RMS error:
- After six coefficients (A-F) are estimated, the digitized coordinates of the first control point can be used as the inputs (the x and y values) to compute the X and Y values, respectively
- If the digitized control points were perfectly located, the computed X and Y values would be identical to the control point's real-world values.
- The deviations between the computed (estimated) X and Y values and the actual coordinates then become errors associated with the first control point on the output.
- Mathematically the input or output errors for a control points is computed by

$$\sqrt{(x_{act} - x_{est})^2 + (y_{act} - y_{est})^2}$$

  Where xact and yact are the x and y values of the actual location and xest and yest are the x and y values of the estimated location.
- The average rms error can be computed by averaging errors from all control points:

$$\sqrt{\sum_{i=1}^{n}(x_{act,i} - x_{est,i})^2 + \sum_{i=1}^{n}(y_{act,i} - y_{est,i})^2 / n}$$

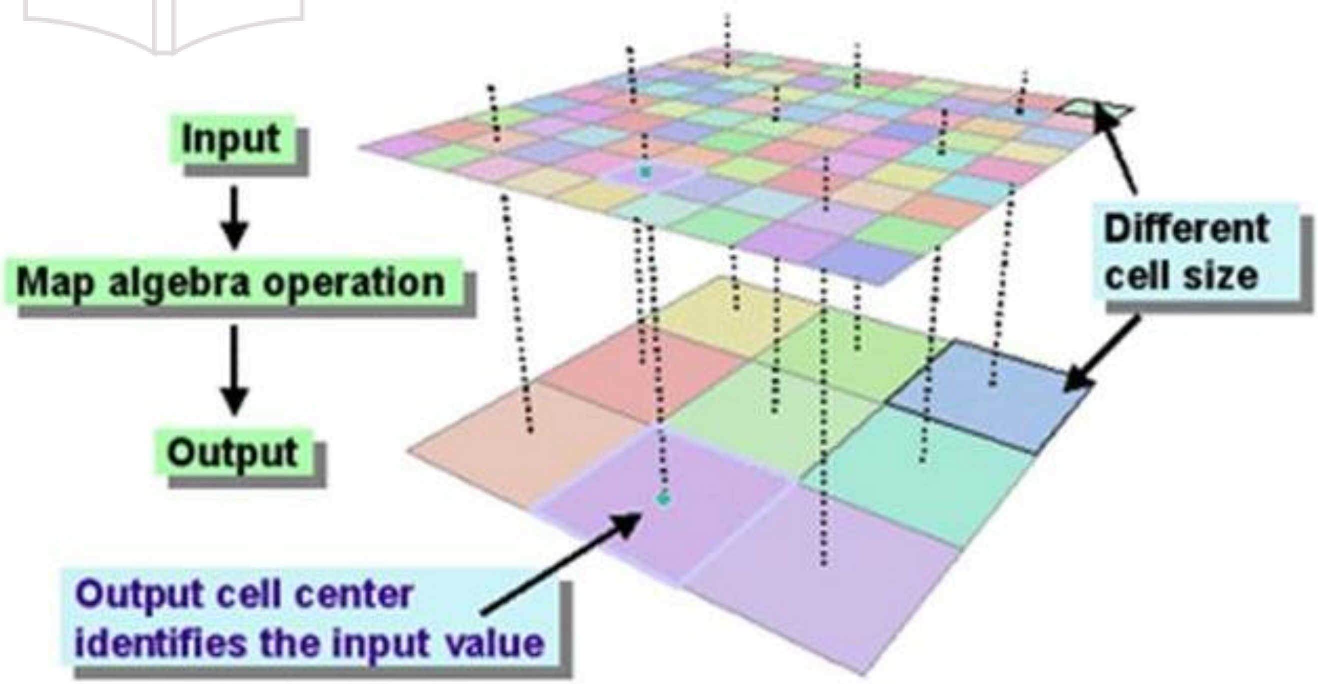
- Where n is the no. of control points
  o xact,i and yact,i are the x and y values of the actual location of control point i
  o xest,i and yest,i are the x and y values of the estimated location of control point i
- If the RMS errors exceed the established tolerance, then control points need to be adjusted
- Interpretation of RMS errors on Digitized Maps
- If a RMS error is within acceptable range, assumption of accurate transformation
- If errors are made in digitizing control points or inputting latitude and longitude of control points, transformation can still be wrong!
- Latitude/Longitude on paper maps erroneous
- Inaccurate placement of control points will lead to errors in transformation

Interpretation of RMS errors on digitized map

Figure 1. Control points (red) evenly distributed. To the left, they surround – or cover – the most of the features that are of interest to analyze/digitize (here symbolized by grey area). To the right, those features are outside of the control points, and there is a greater risk that the transformation includes more errors on these features.

Pixel value resampling

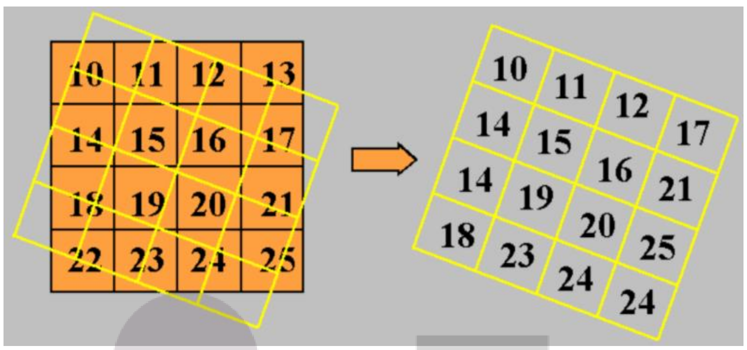
- The geometric transformation of a satellite image results in a new image based on a projected coordinate system – but the new image has no pixel values
- Resampling is the process of determining new values for cells in an output raster that result from applying a geometric transformation to an input raster dataset.
- The three techniques for determining output values are:
  o Nearest neighbor
  o Bilinear interpolation
  o Cubic convolution.

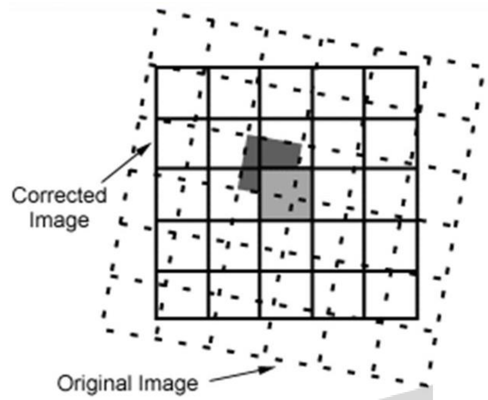


Nearest Neighbor

- Nearest Neighbor resampling method fills each pixel of the new image with the nearest pixel value from the original image
- To determine the nearest neighbor, the algorithm uses the inverse of the transformation matrix to calculate the image file coordinates of the desired geographic coordinate.
- The pixel value occupying the closest image file coordinate to the estimated coordinate will be used for the output pixel value in the georeferenced image.

NEAREST NEIGHBOR RESAMPLING





Nearest neighbor
Advantages:

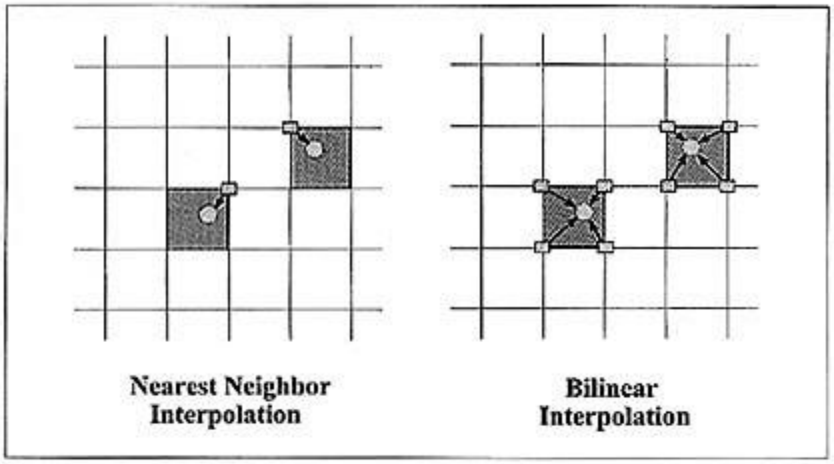
- Output values are the original input values. Other methods of resampling tend to average surrounding values. This may be an important consideration when discriminating between vegetation types or locating boundaries.
- Since original data are retained, this method is recommended before classification.
- Easy to compute and therefore fastest to use.

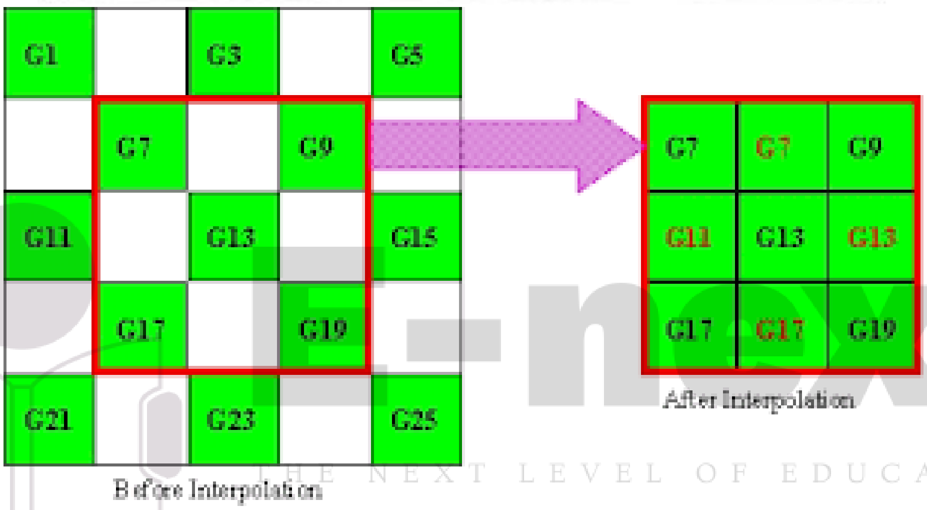
Disadvantages:

- Produces a choppy, "stair-stepped" effect. The image has a rough appearance relative to the original unrectified data.
- Data values may be lost, while other values may be duplicated. Figure 1 shows an input file (orange) with a yellow output file superimposed. Input values closest to the center of each output cell are sent to the output file to the right. Notice that values 13 and 22 are lost while values 14 and 24 are duplicated.

Bilinear interpolation

- Bilinear interpolation uses the value of the four nearest input cell centers to determine the value on the output raster.
- The new value for the output cell is a weighted average of these four values, adjusted to account for their distance from the center of the output cell in the input raster.
- This interpolation method results in a smoother-looking surface than can be obtained using nearest neighbor.
- Preferred for continuous data (elevation, slope, salinity, etc.)





Bilinear interpolation

Advantages:

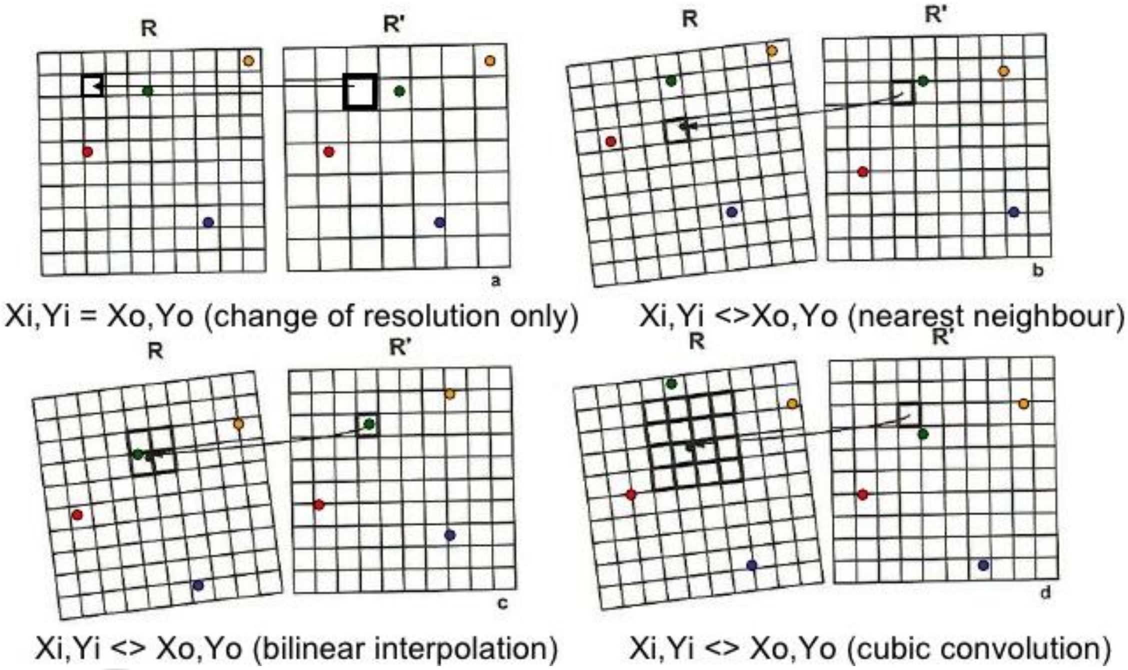
- Stair-step effect caused by the nearest neighbor approach is reduced. Image looks smooth.

Disadvantages:

- Alters original data and reduces contrast by averaging neighboring values together.
- Is computationally more expensive than nearest neighbor.

Cubic convolution

- The weighted average is calculated from the 16 nearest input cell centers and their values.
- The output is similar to bilinear interpolation, but the smoothing effect caused by the averaging of surrounding input pixel values is more dramatic.
- Cubic convolution will have a tendency to sharpen the data more than bilinear interpolation since more cells are involved in the calculation of the output value.



Cubic convolution

Advantages:

- Stair-step effect caused by the nearest neighbor approach is reduced. Image looks smooth.

Disadvantages:

- Alters original data and reduces contrast by averaging neighboring values together.
- Is computationally more expensive than nearest neighbor or bilinear interpolation.